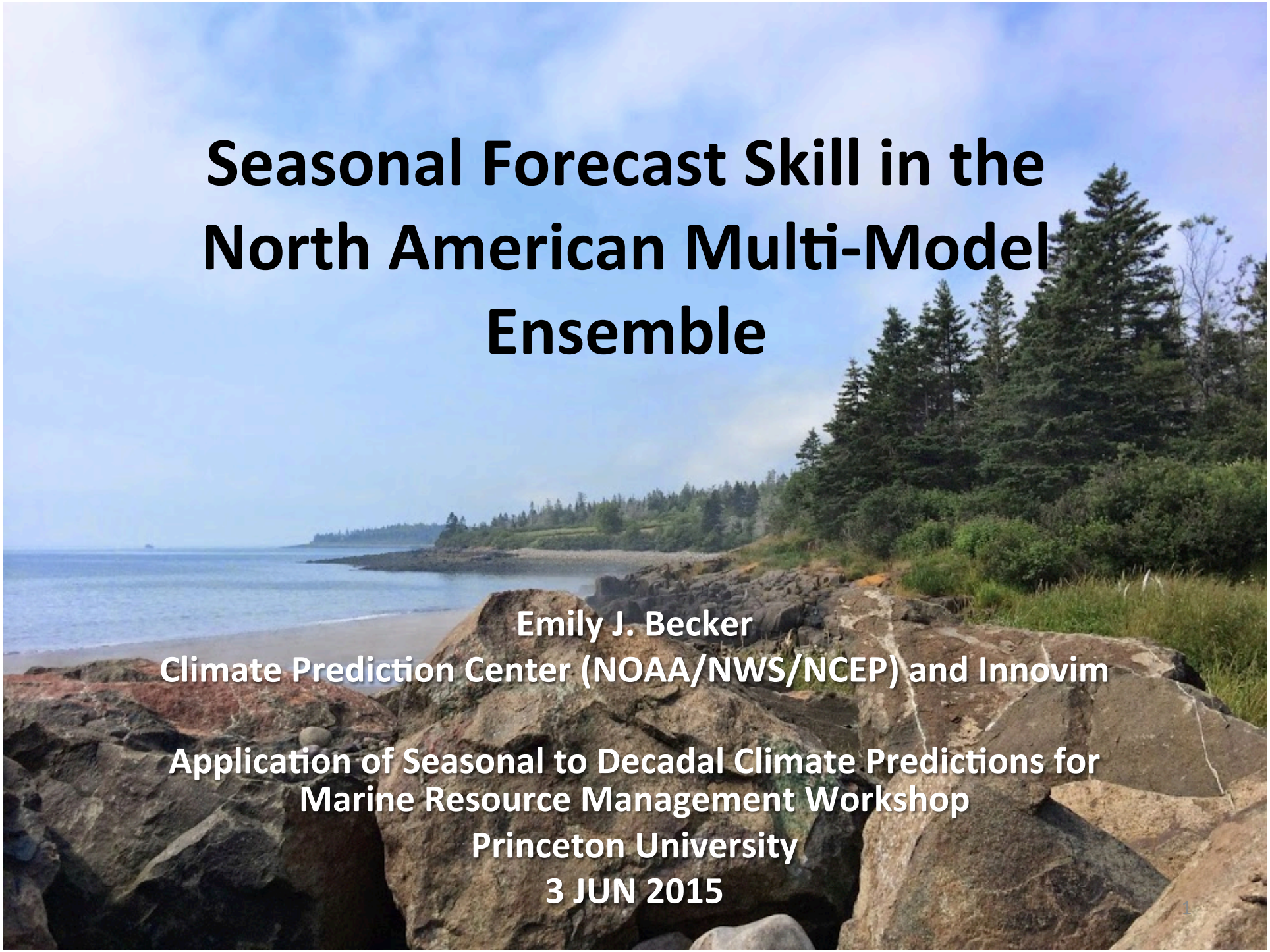
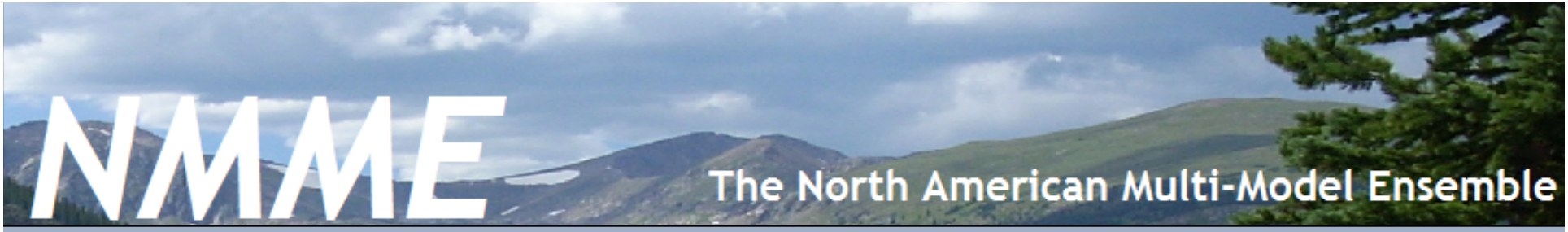


Seasonal Forecast Skill in the North American Multi-Model Ensemble

Emily J. Becker
Climate Prediction Center (NOAA/NWS/NCEP) and Innovim

Application of Seasonal to Decadal Climate Predictions for Marine Resource Management Workshop
Princeton University
3 JUN 2015



- **NMME** (North American Multi-Model Ensemble) is an unprecedented MME system intended to improve intra-seasonal to interannual (ISI) operational predictions based on the leading US and Canada climate models.
- Seasonal forecasting guidance available monthly, following CPC operational forecasting schedule, since August, 2011.
- All participating models strictly follow the same protocol.

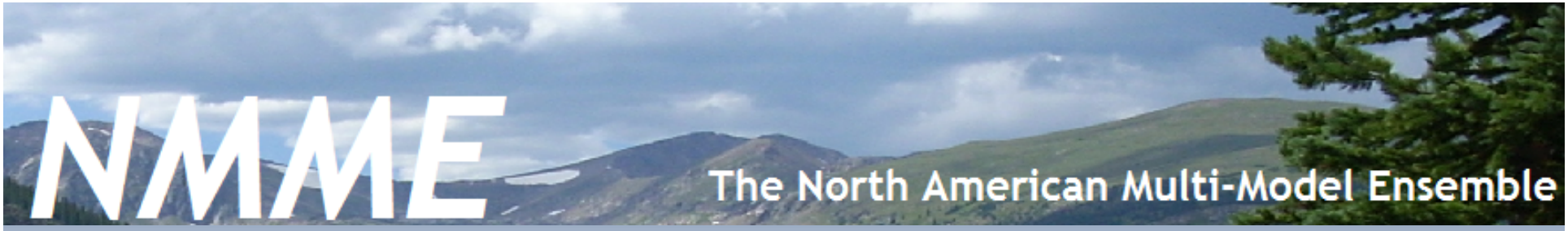
www.cpc.ncep.noaa.gov/products/NMME

Why MME? Why the NMME?

- Models are imperfect: biases and poor estimations of their own skill.
- Performance of multi-model ensembles is better than single models; skill increase comes from error cancellation and non-linearity of diagnostics.
- Several earlier projects (DEMETER, ENSEMBLES, etc.) have tested the theory of MME.
- Ensembles allow for characterization of uncertainty.
- Users require predictions with minimal uncertainty accompanied by reliable estimates of that uncertainty.
- NCEP was recommended by the National Research Council to implement an NMME system to improve ISI forecasting.

Palmer et al. (2004), BAMS

National Research Council (2010)



Developing the NMME

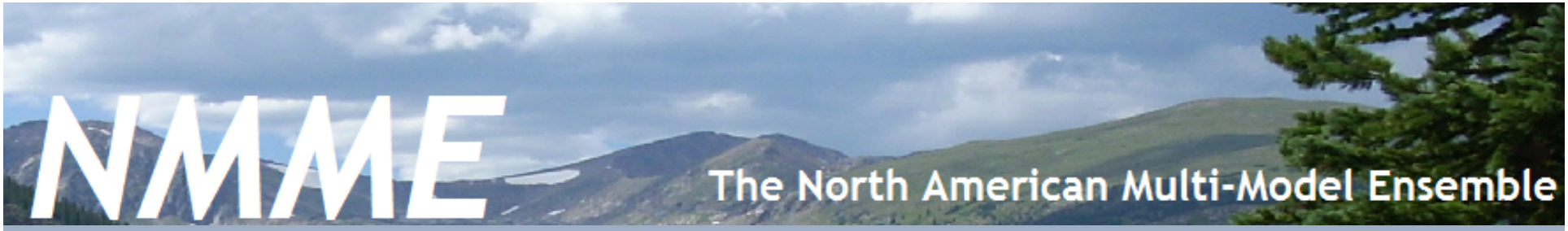
- Initial planning meetings in February and April of 2011 held by NOAA's Climate Test Bed (CTB) to bring together the participants.
- First forecasts issued in August 2011.
- All major US global coupled atmosphere-ocean climate models were represented (Canadian models joined Year 2).
- **NMME Phase-I**: An experimental system initiated as a Climate Test Bed (CTB) research project supported by CPO/ MAPP in FY11. "NMME of opportunity."
- **NMME Phase-II**: An improved experimental system as a FY12-FY13 MAPP/CTB research project with additional support from NSF, DOE and NASA. Includes subseasonal timescales.

Kirtman et al. (2014), BAMS

Phase I protocol

- Monthly-mean forecasts
- Specifications:
  - 1° longitude x 1° latitude horizontal resolution
  - 3 primary variables
    - 2 m surface temperature
    - Sea surface temperature
    - Precipitation rate
  - Hindcasts from 1982-2010 (at least)
  - At least 9-month lead forecasts
  - Delivered by 1700h Eastern on the 8th of each month
- All data (hindcast and forecast) is archived and available to the public.

http://iridl.ldeo.columbia.edu/SOURCES/.Models/.NMME/



MODELS Aug 2011 - present

- Four models continue from year 1
  - CFSv2, GFDL CM2.1, NASA GEOS5, NCAR CCSM3
  - CFSv1, IRI's ECHAMa and ECHAMf retired Aug. 2012
- Two models continue from year 2
  - EC's CanCM3, CanCM4
- GFDL's FLORa06 and b01 introduced in March
  - Combined into one for RT forecasts starting May 2014
- NCAR CCSM4 introduced in May

www.cpc.ncep.noaa.gov/products/NMME

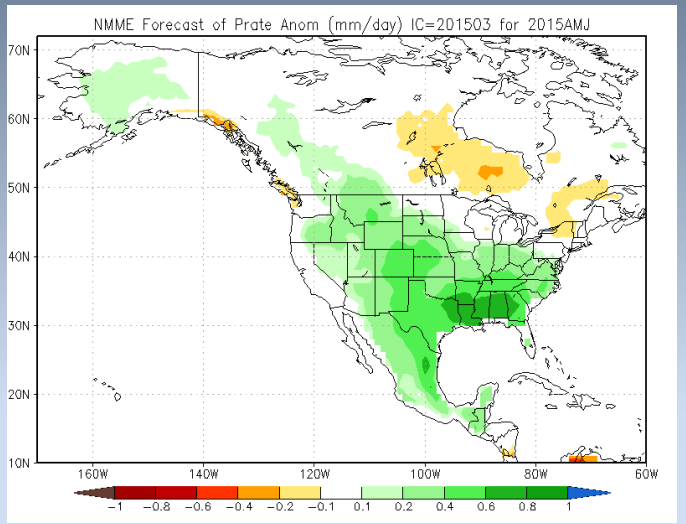
Model	Hindcast Period	No. of Members	Arrangement of Members	Lead (month)	Model resolution (atmos)	Model resolution (ocean)	Reference
Active							
NCEP/CFSv2	1982-2010	24 (28)	4 members (0, 6, 12, 18z) every 5th day	0-9	T126L64	MOM4L40 .25deg Eq	Saha et al (2010)
GFDL/CM2.1	1982-2010	10	All 1st of the month 0Z	0-11	2x2.5degL24	MOM4L50 .3deg Eq	Delworth (2006)
GFDL/CM2.5 (FLOR)	1982-present	24	All 1st of the month 0Z	0-11	C18L32 (50km)	MOM5 L50 0.30 deg Eq 1degPolar1.5	Vecchi et al (2014)
CMC1-CanCM3	1981-2010	10	All 1st of the month 0Z	0-11	CanAM3 T63L31	CanOM4L40 .94deg Eq	Merryfield et al (2013)
CMC1-CanCM4	1981-2010	10	All 1st of the month 0Z	0-11	CanAM4 T63L35	CanOM4L40 .94deg Eq	Merryfield et al (2013)
NCAR/CCSM4	1982-2010	10	All 1st of the month 0Z	0-11	0.9x1.25degL26	POPL60 .25deg Eq	Kirtman et al. (in prep)
NASA/GEOS5	1981-2010	11	4 mems every 5 days; 7 mems on last day of last month	0-9	1x1.25 deg L72	MOM4L40 .25deg Eq	Vernieres et al (2012)
Retired							
NCEP/CFSv1	1982-2009	15	1st 0Z +/-2 days, 21st 0z +/-2d, 11th 0z +/-2d	0-8	T62L64	MOM3L40 0.30 deq Eq	Saha et al (2006)
NCAR/CCSM3	1982-2010	6	All 1st of the month 0Z	0-11	T85L26	POPL42 0.3deg Eq	Kirtman and Min2009)
IRI-ECHAM4f	1982-2010	12	All 1st of the month 0Z	0-7	T42L19	MOM3L25(1.5x0.5)	DeWitt (2005)
IRI-ECHAM4a	1982-2010	12	All 1st of the month 0Z	0-7	T42L19	MOM3L25 (1.5x0.5)	DeWitt (2005)
Planned							
NCAR/CESM1	1982-2010	10	All 1st of the month 0Z	0-11	0.9x1.25degL30	POPL60 .25deg Eq	Tribbia et al.

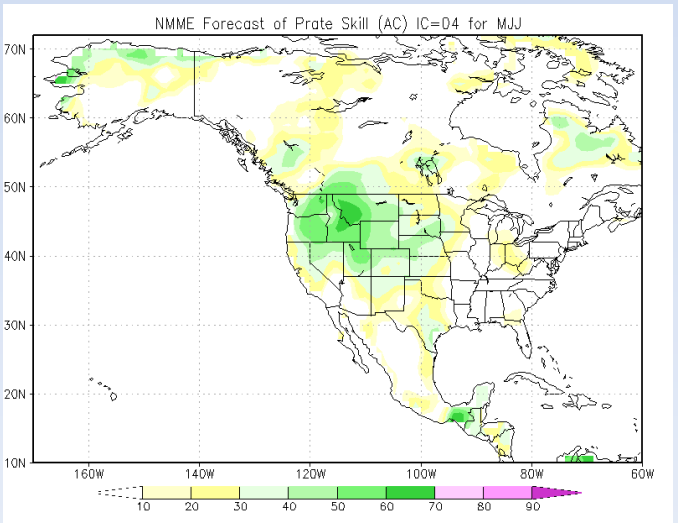
NMME

The North American Multi-Model Ensemble

Phase I products

- 2 m temperature, precip rate, SST
- Available forecasts and products, August 2011:
  - 1-month mean spatial anomalies
  - 3-month mean spatial anomalies
  - Niño3.4 plumes
  - Skill maps based on anomaly correlation from hindcasts



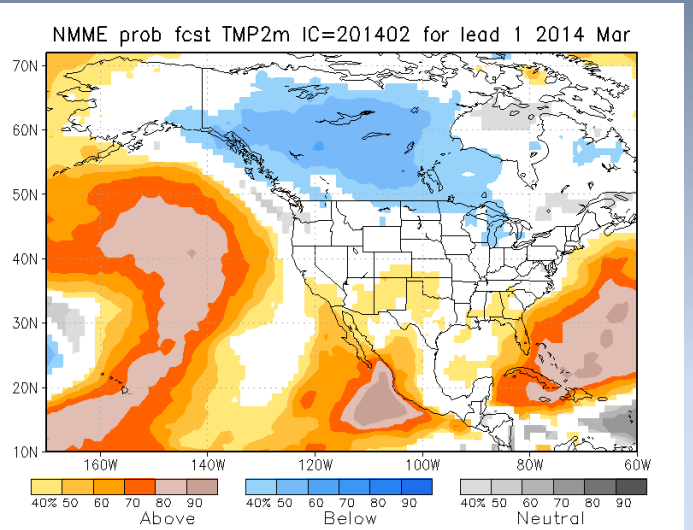


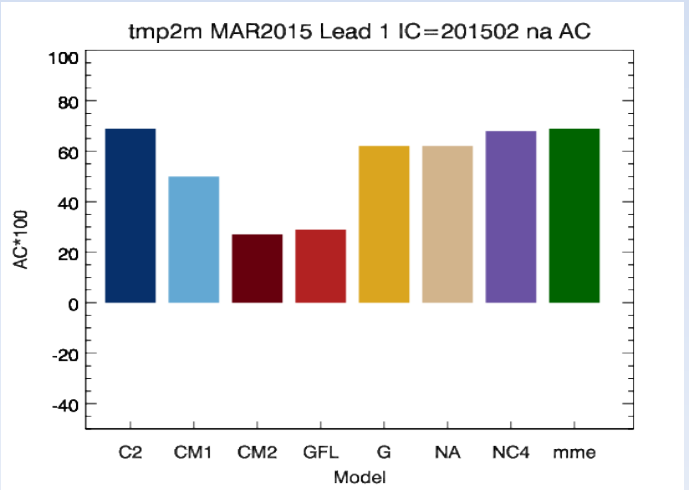
NMME

The North American Multi-Model Ensemble

Phase I products

- Experimental probability forecasts (Nov. 2012)
- Deterministic forecasts of additional variables: 200 hPa heights, Tmax, Tmin, soil moisture*, runoff* (May 2013)
- Real-time verif. (Nov. 2013)
- Probabilistic Tmax/Tmin forecasts (June 2015)

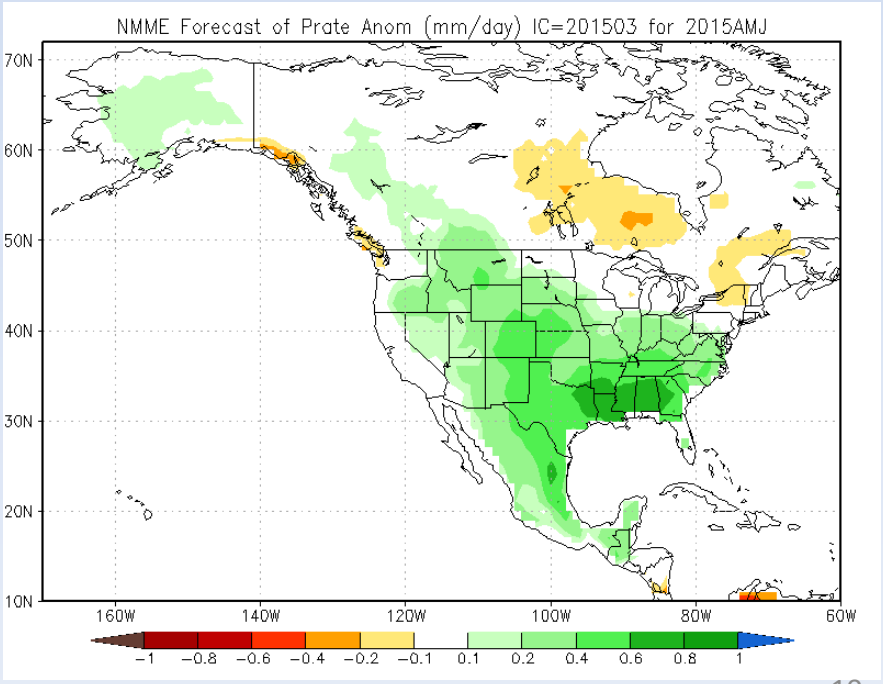




Deterministic forecasts

- Forecast for a precise value
- Bias-corrected ensemble mean anomalies: anomalies are calculated using model's climatology (from hindcasts)
- Multi-model ensemble mean uses **equal weighting** for each model: NMME=(EM_1+EM_2+…+EM_N)/N

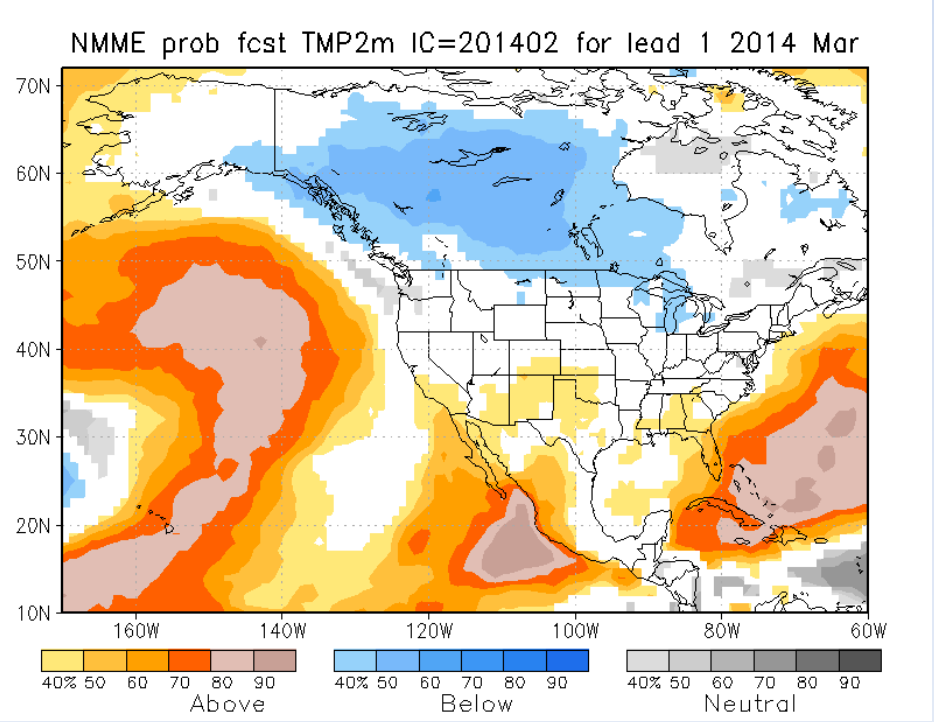
- Available for individual models and for MME
- Skill maps for each model and NMME
- Common skill measures: Anomaly correlation, RMSE



Probabilistic forecasts

- Terciles (above, near-normal, below)
- Tercile thresholds determined using parametric fits on the hindcasts of individual models
- **Above: > mean + 0.43σ, Below: < mean – 0.43σ**

- Forecast members are assigned to terciles; number of members in each class is counted
- Realtime forecast: > 100 members
- Each member is counted with equal weight: models with more members contribute more to the forecast

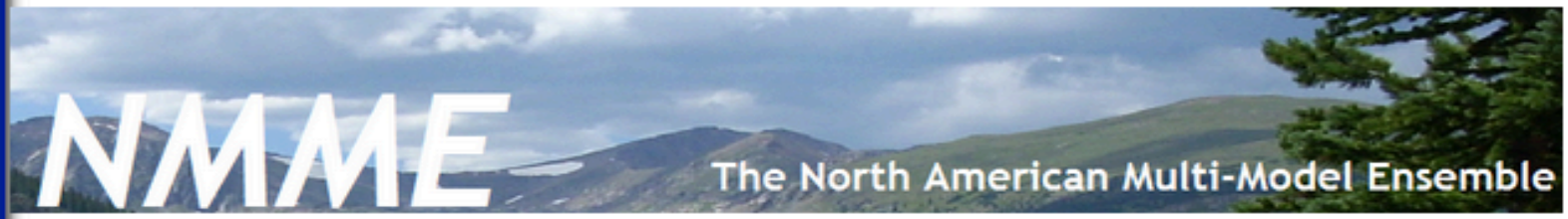


National Weather Service

Climate Prediction Center

Home | Site Map | News | Organization

HOME > NMME Forecasts of Monthly Climate Anomalies



Welcome to the North American Multi-Model Ensemble home!

3-month mean spatial anomalies
1-month mean spatial anomalies

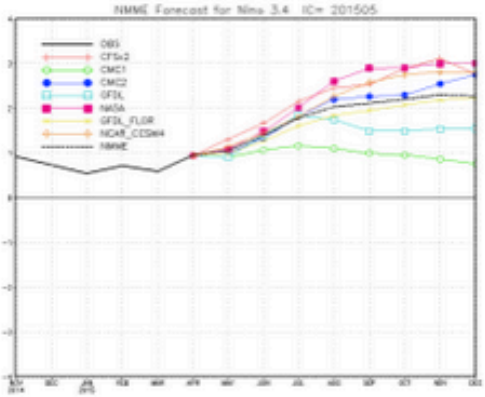
Niño3.4 Plumes
International MME
Experimental: Probability forecasts
Preview: additional variables
Real-time verification (preliminary)

NMME Realtime Forecasts **Archive**
***** Data Access *****

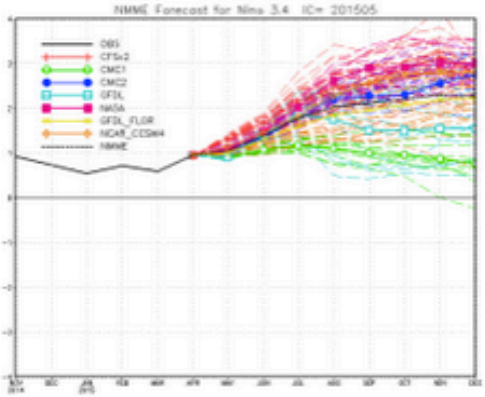
About the NMME
Join the NMME mailing list

For additional information, contact Qin Zhang (**Qin.Zhang@noaa.gov**) or Emily Becker (**Emily.Becker@noaa.gov**)

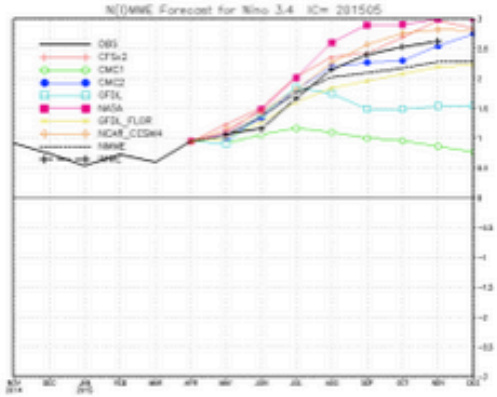
Ensemble Mean



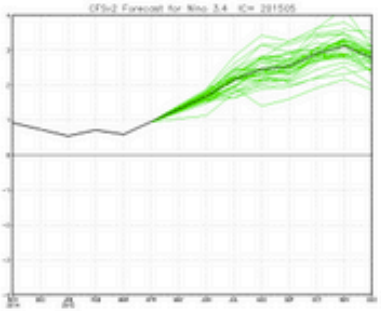
All Members



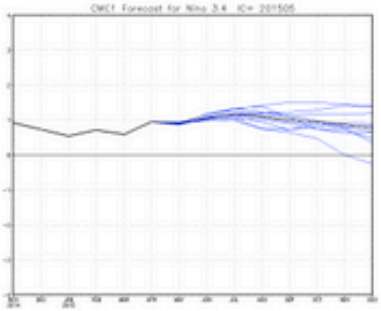
Ens Mean + IMME



CFSv2_CFSv2



CMC1_CanCM3



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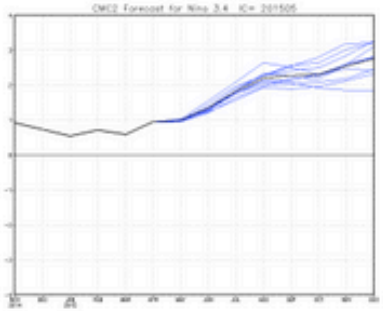
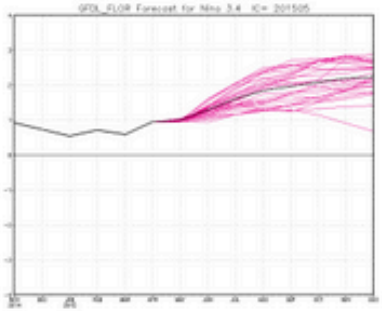


GFDL_FLOR



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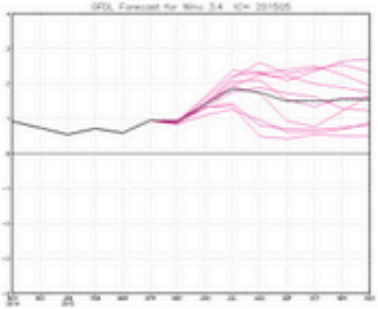

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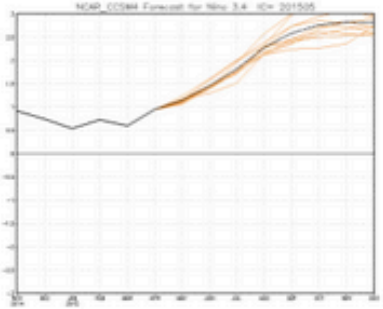
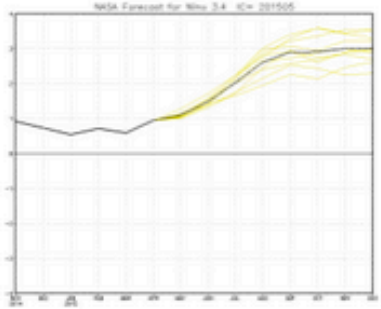


NASA_GEOS5



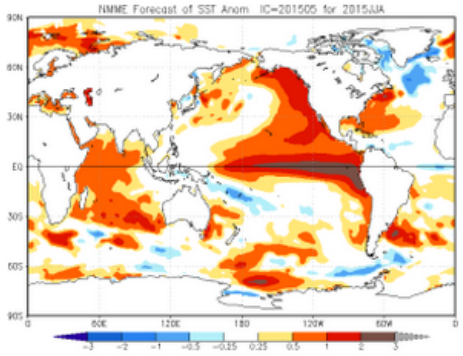
Season 1 tmpsfc

www.cpc.ncep.noaa.gov/products/NMME/current/tmpsfc_Seas1.html

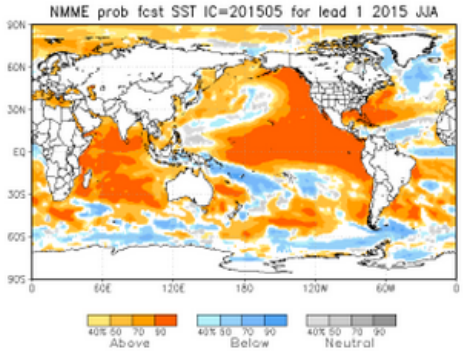
Apps | Inbox - ejbecker@g... | 7-Day Forecast | CPC | NMME | College Park, Maryla... | Soil Moisture Monit... | Other bookmarks

Season 1 tmpsfc forecast

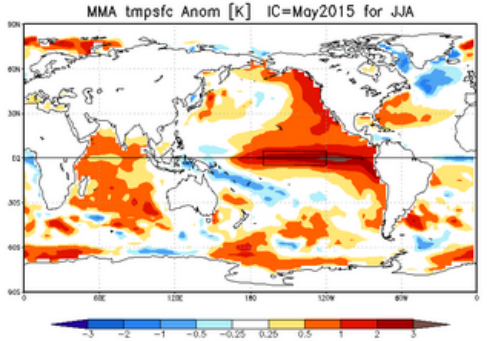
NMME



Prob fcst



IMME



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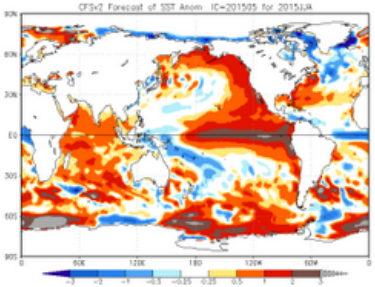

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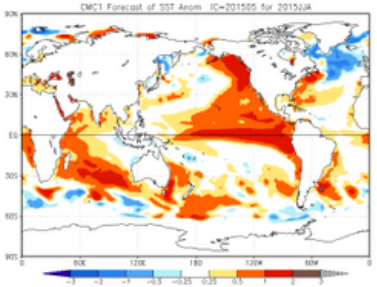
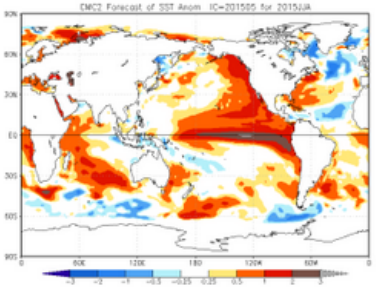
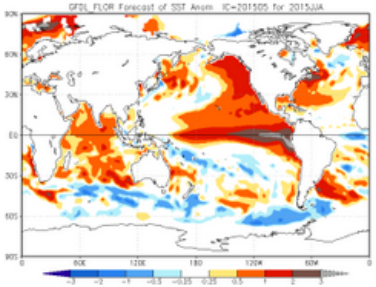


CMC2_CanCM4



GFDL_FLOR



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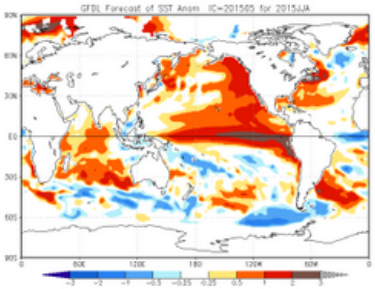

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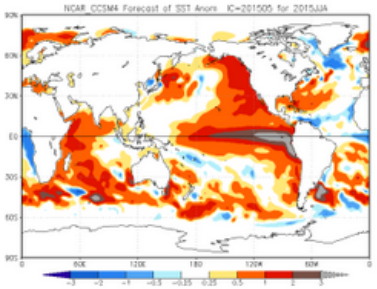

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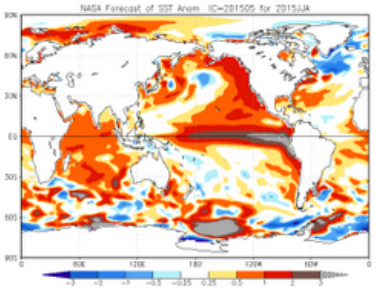

Season 1 tmpsfc

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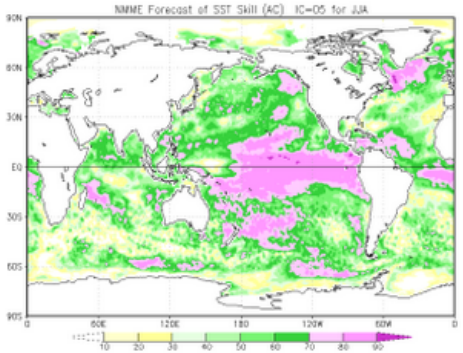
Season 1 tmpsfc forecast

NMME



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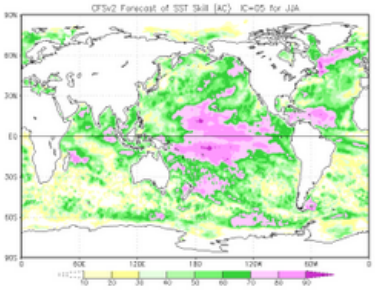

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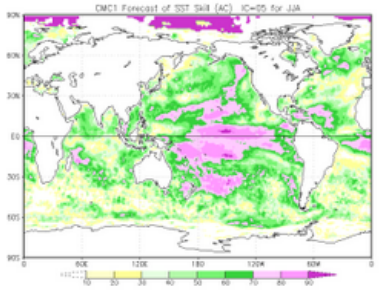

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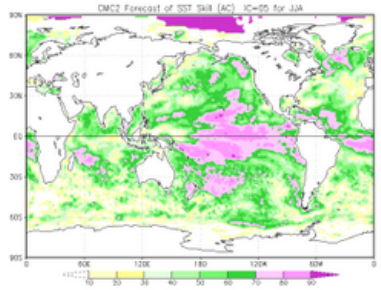

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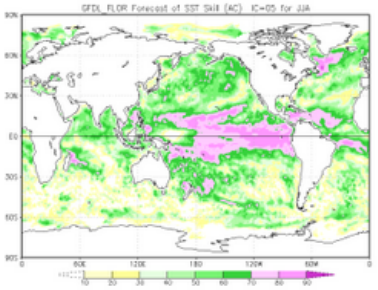

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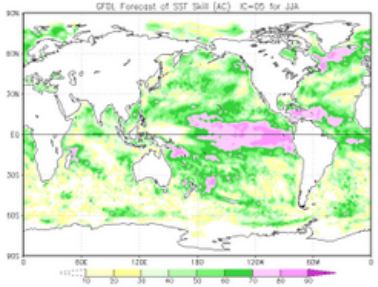

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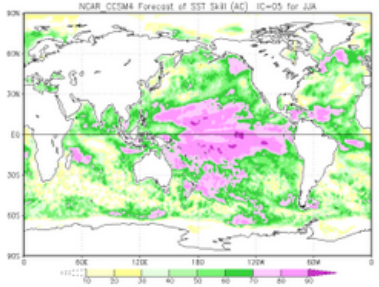

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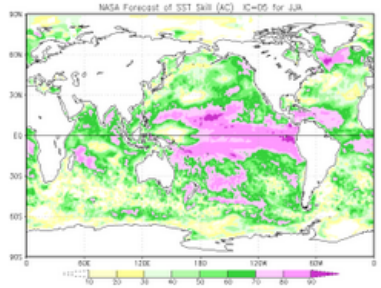
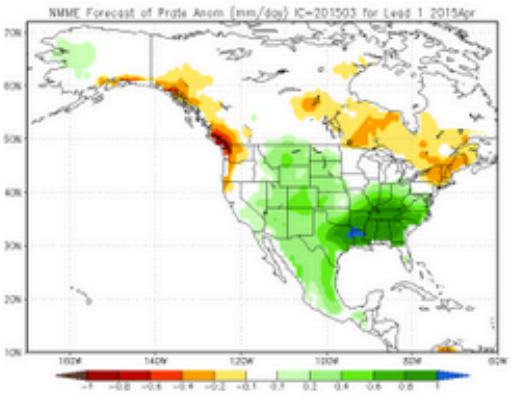
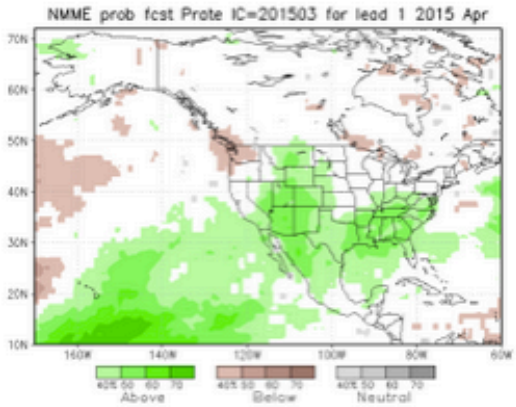


NMME



Prob fcst



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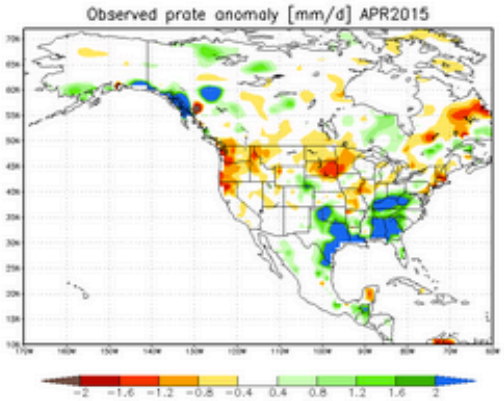
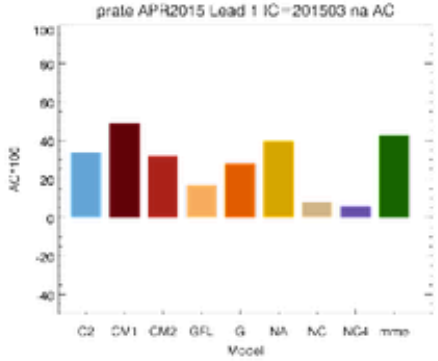
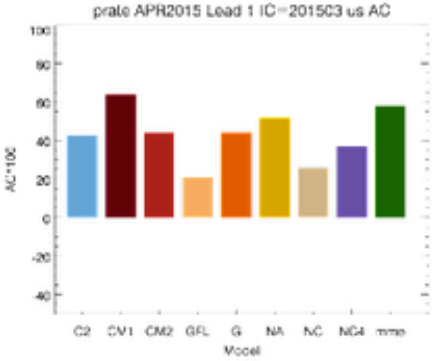


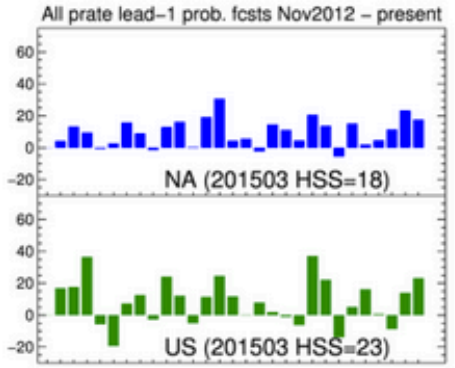
North Amer. AC



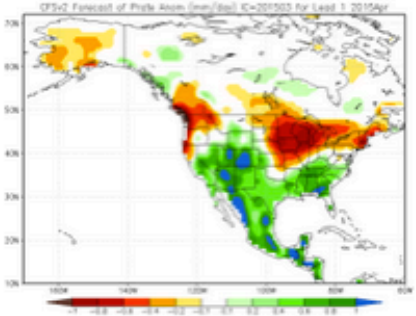
CONUS AC



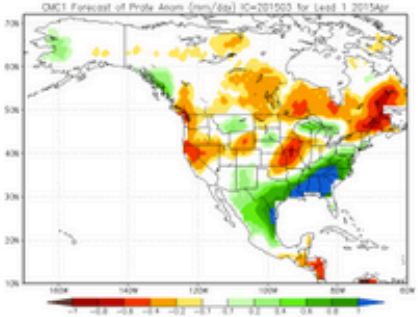
Heidke SS



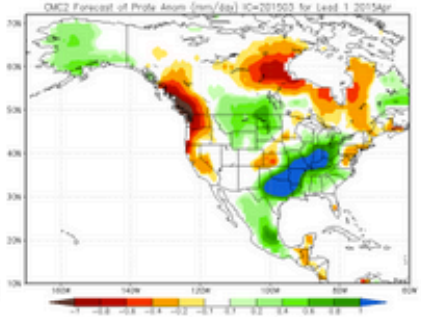
NCEP_CFSv2



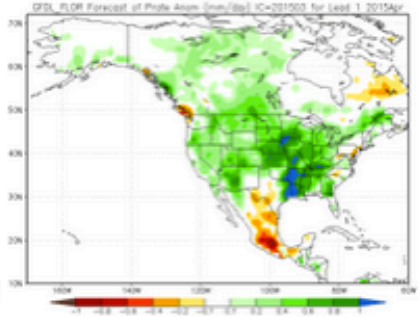
CMC1_CanCM3

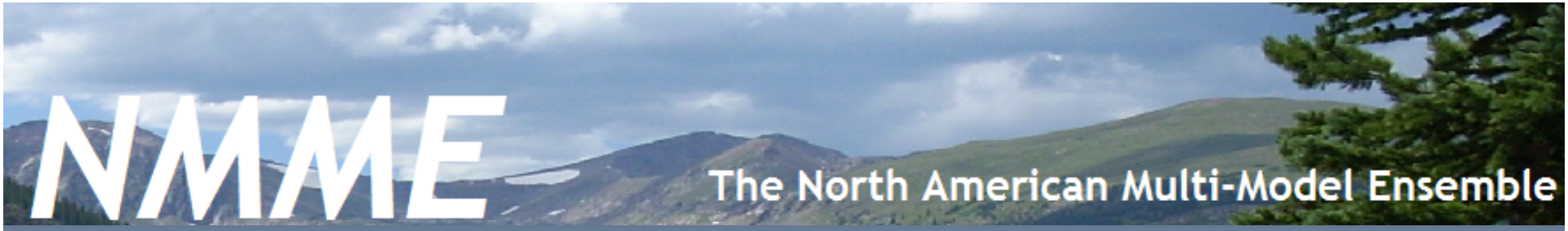


CMC2_CanCM4



GFDL_FLOR

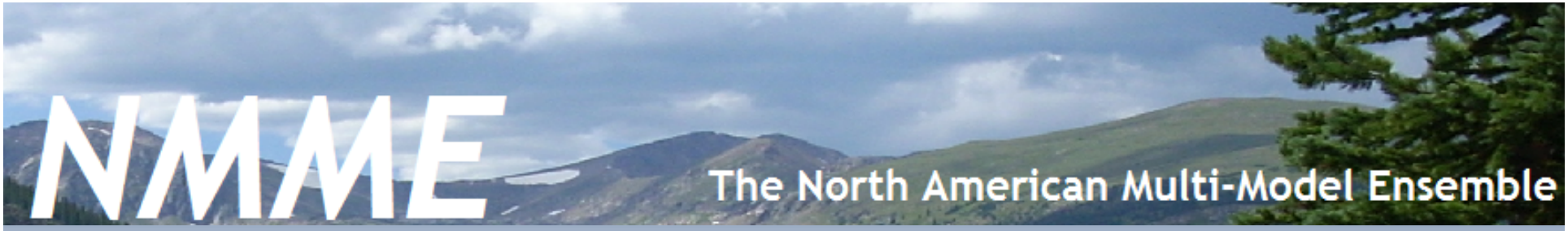




Phase II

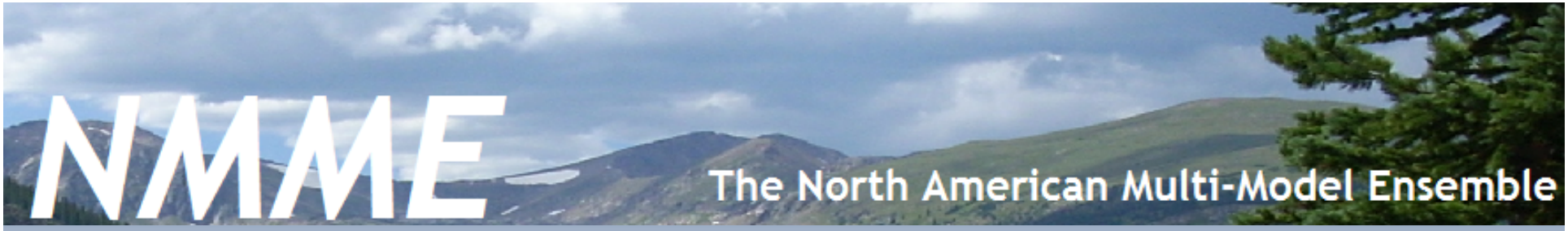
- Subseasonal (45-day forecasts) and seasonal
- 33 years of hindcasts + realtime forecasts
- 30+ atmospheric and land fields and 9 ocean and sea-ice fields (13 ocean levels)
- 360x181 degree horizontal resolution
- NetCDF format

https://www.earthsystemgrid.org/search.html?Project=NMME



Hindcast studies of model performance and prediction skill

How well do the NMME models predict SST, T2m, and precip rate?

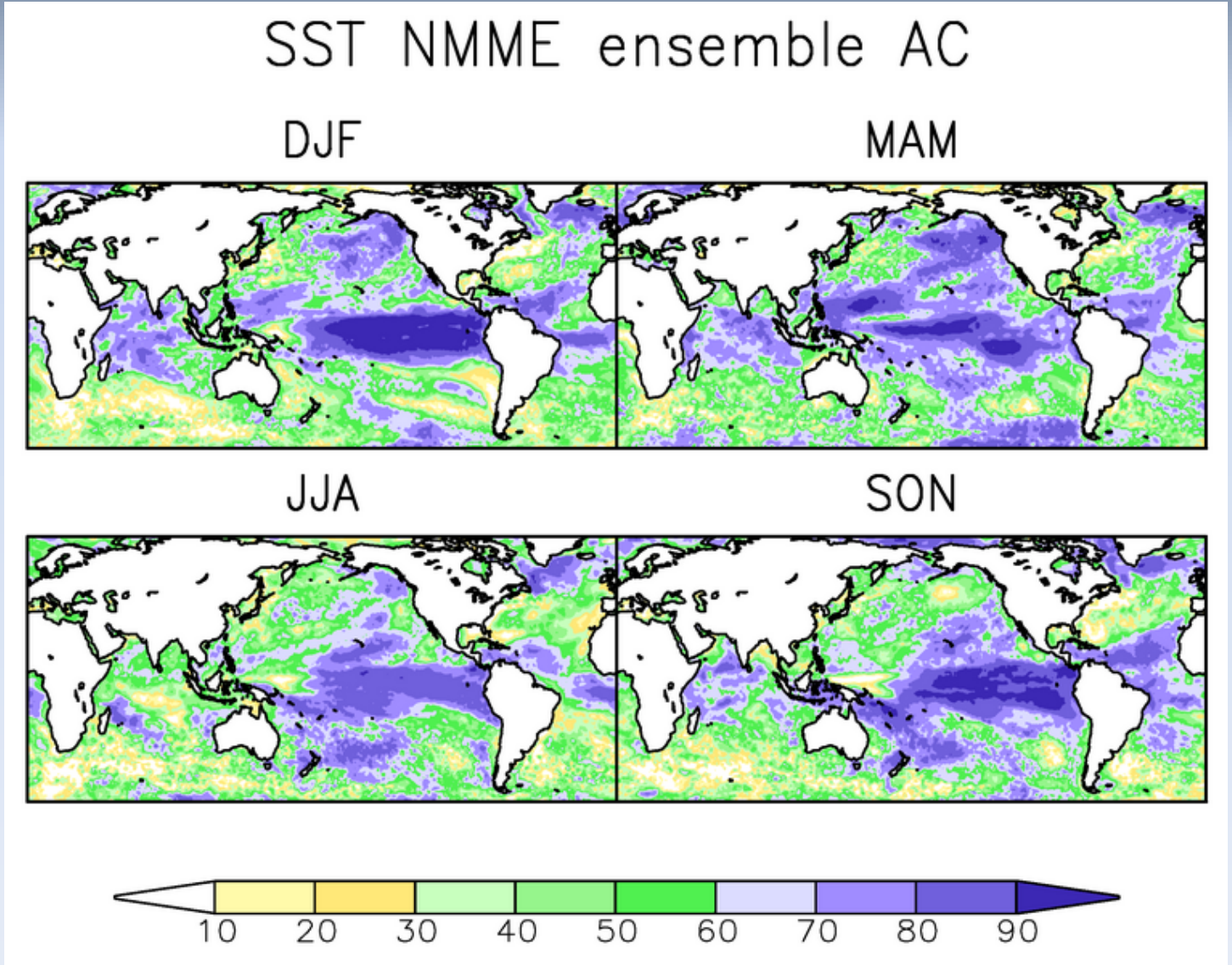


Hindcast studies of deterministic forecasts

- Forecast skill and potential predictability of 2-m temperature, precipitation rate, and sea surface temperature are assessed using 29 yrs of hindcast data from models included in Phase 1 of the North American Multimodel Ensemble (NMME) project.
- 7 models: CFSv1, CFSv2, CanCM3, CanCM4, CM2.5, GEOS5, CCSM3
- Skill of the bias-corrected ensemble means (EMs) of the individual models and of the NMME 7-model EM are verified against the (single) observed value.
- Anomaly correlation and RMSE

Becker et al. (2014), J. Climate

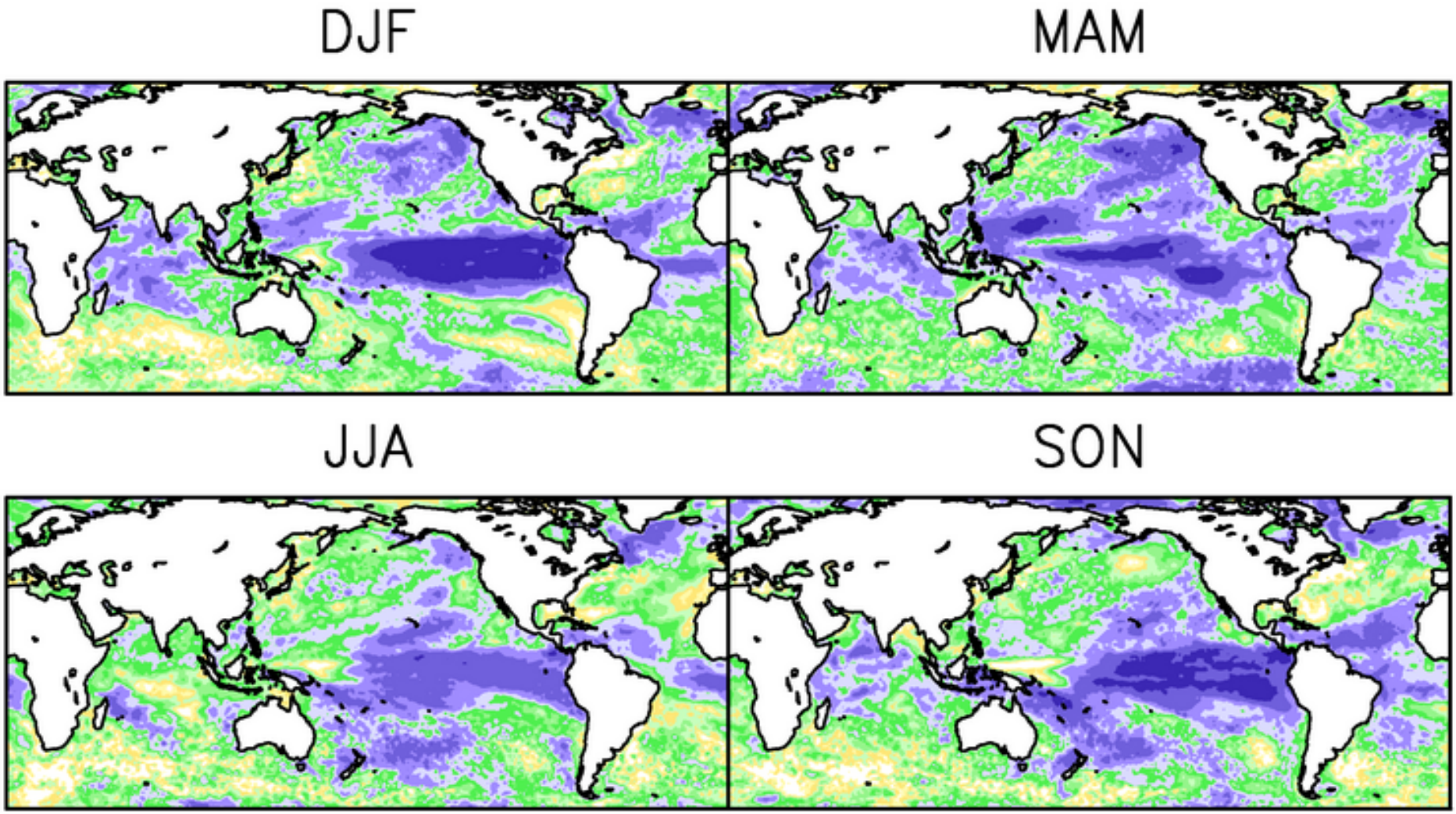
SST lead-1 seasonal forecast



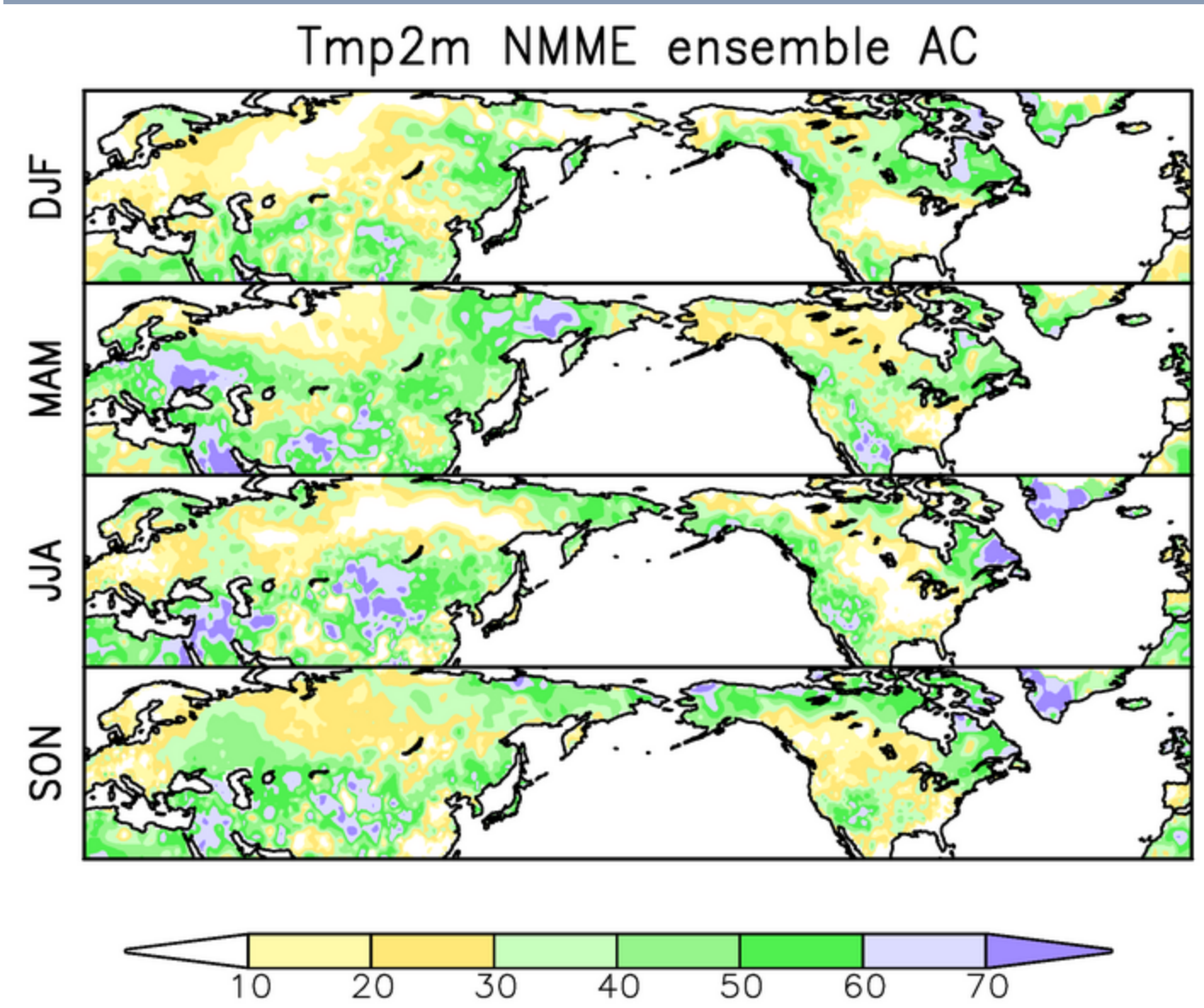
NH AC
CFSv1: 29
CFSv2: 41
CMC1: 44
CMC2: 46
GFDL: 42
NASA: 35
NCAR: 15
NMME=50

Niño3.4 reg.
CFSv1: 82
CFSv2: 82
CMC1: 87
CMC2: 85
GFDL: 80
NASA: 88
NCAR: 80
NMME=89

SST NMME ensemble AC



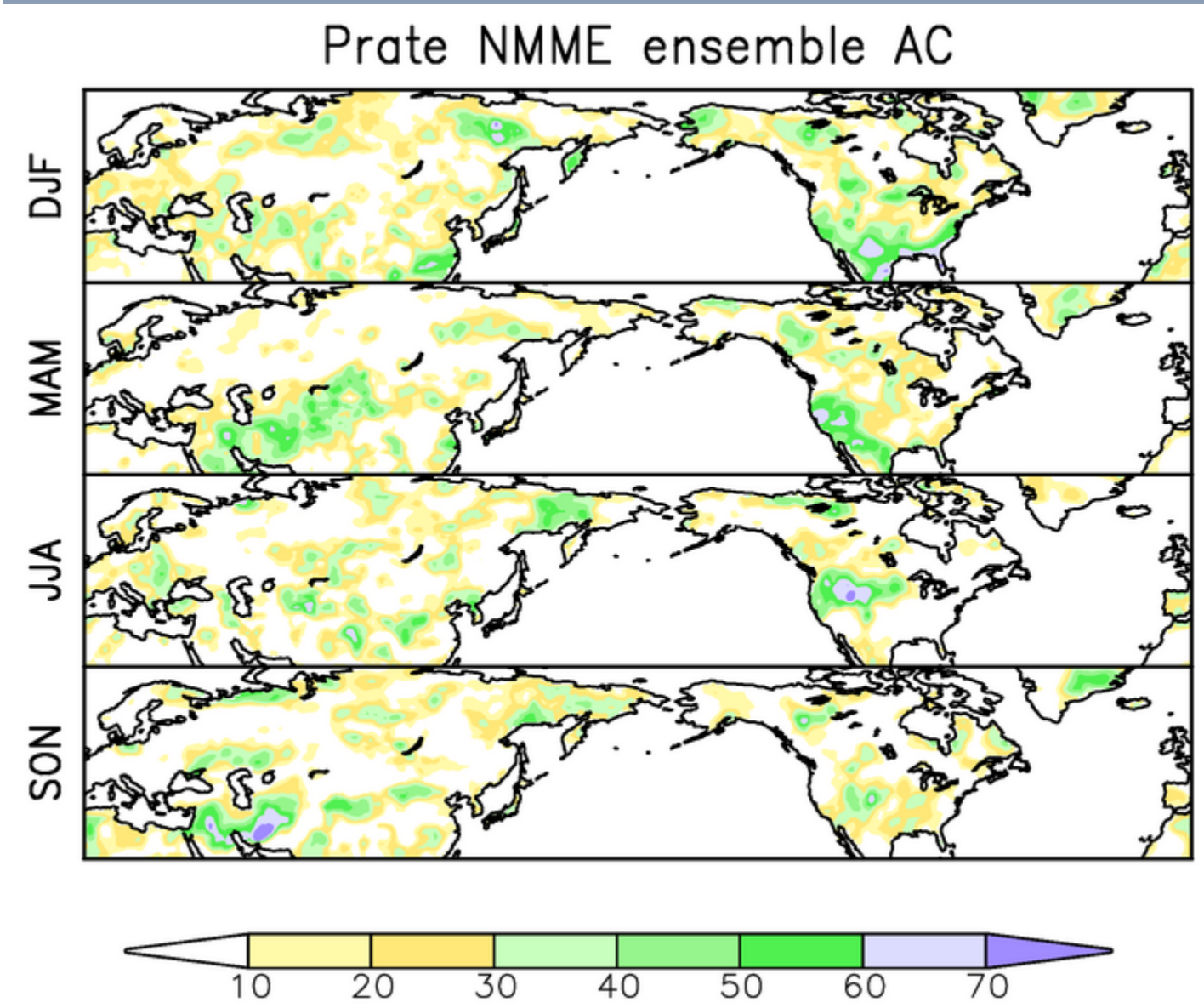
2 m temperature lead-1 seasonal



EM AC
CFSv1: 12
CFSv2: 29
CMC1: 17
CMC2: 27
GFDL: 25
NASA: 23
CCSM3: 0
NMME=29

All lead-1 seasons

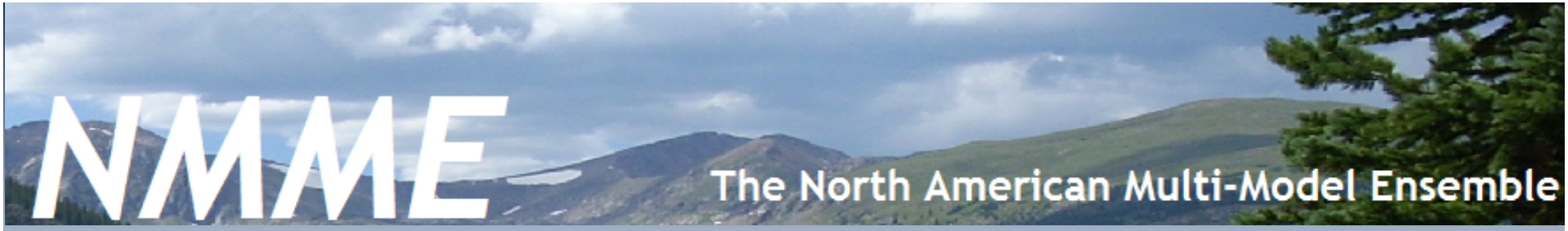
Precipitation rate lead-1 seasonal



EM AC
CFSv1: 10
CFSv2: 12
CMC1: 9
CMC2: 11
GFDL: 12
NASA: 9
CCSM3: 4
NMME=16

Comments on skill of deterministic forecasts

- Coastal North America, especially East coast, has generally poor skill in SST retrospective forecasts
- Alaskan coastal regions SST show higher skill during some seasons
- The NMME 7-model forecast skill, verified against observations, is equal to or higher than the individual models' forecast ACs.
- For two-meter temperature (T2m) skill matches the highest single-model skill, while for precipitation rate and sea surface temperature NMME EM skill is higher than for any single model.

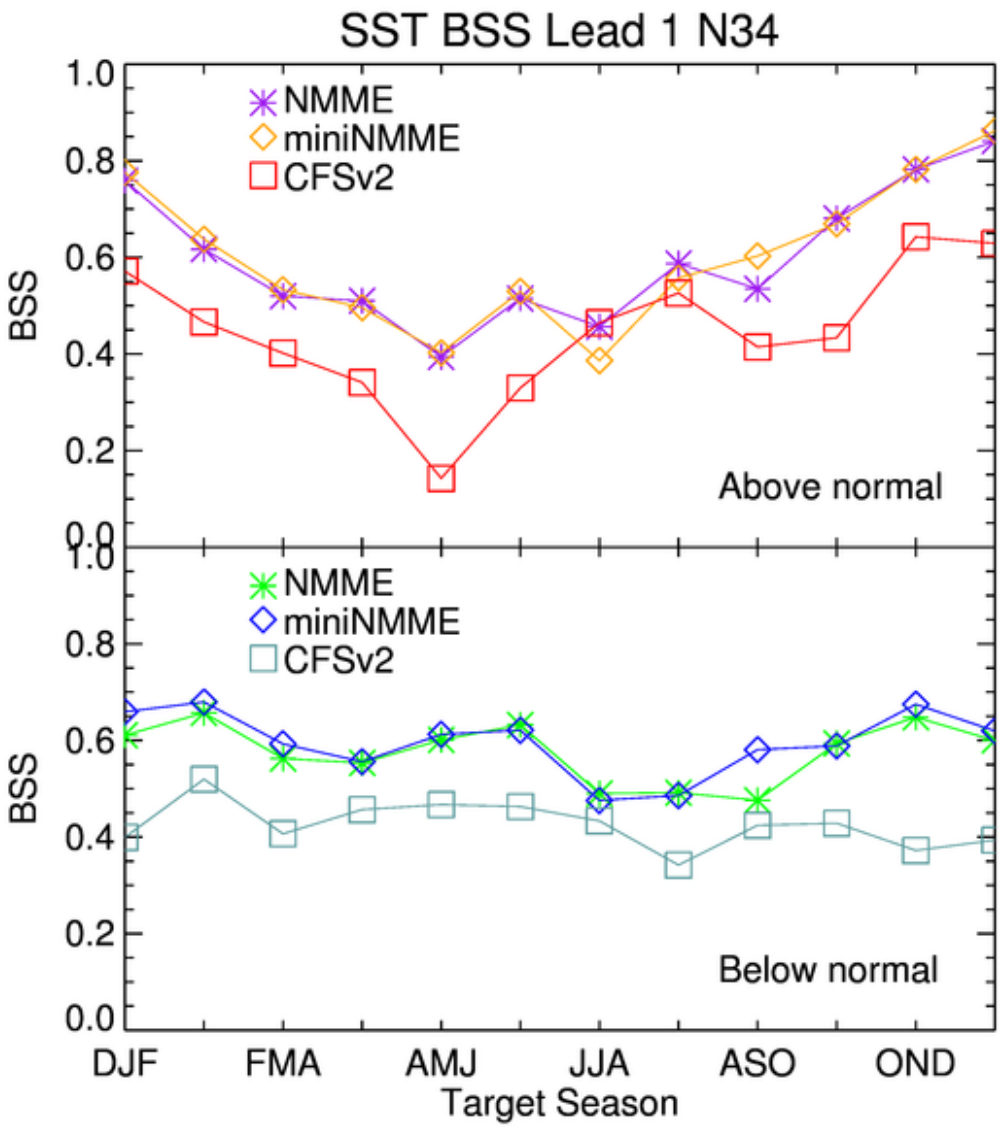


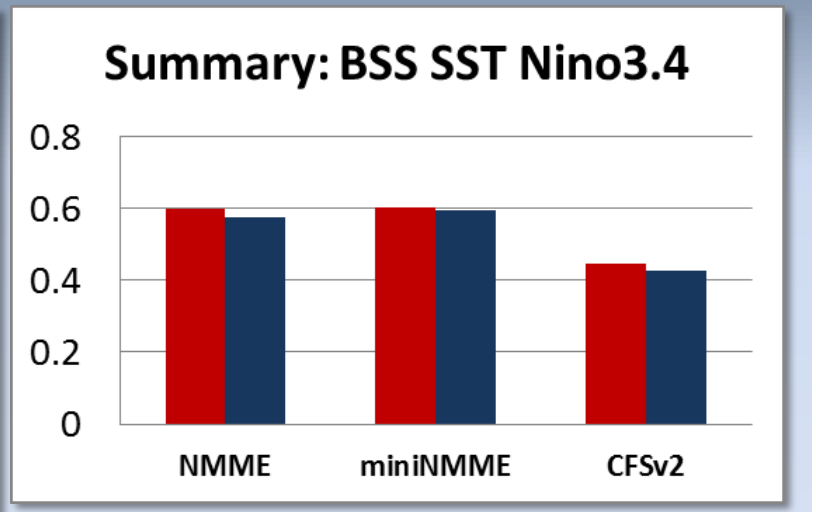
Hindcast studies of probabilistic forecasts

- 6 models with consistent (1982-2010) hindcast records: CFSv2, CanCM3&4, NASA-GEOS5, GFDL-CM2.1, NCAR-CCSM4
- 75 members
- 3 combinations
  - **NMME**: all models, all members
  - **Mini-NMME**: all models, 4 members each
  - **CFSv2**: 24 members
- Brier skill score

Becker and van den Dool (2015) *J. Climate*, in review.

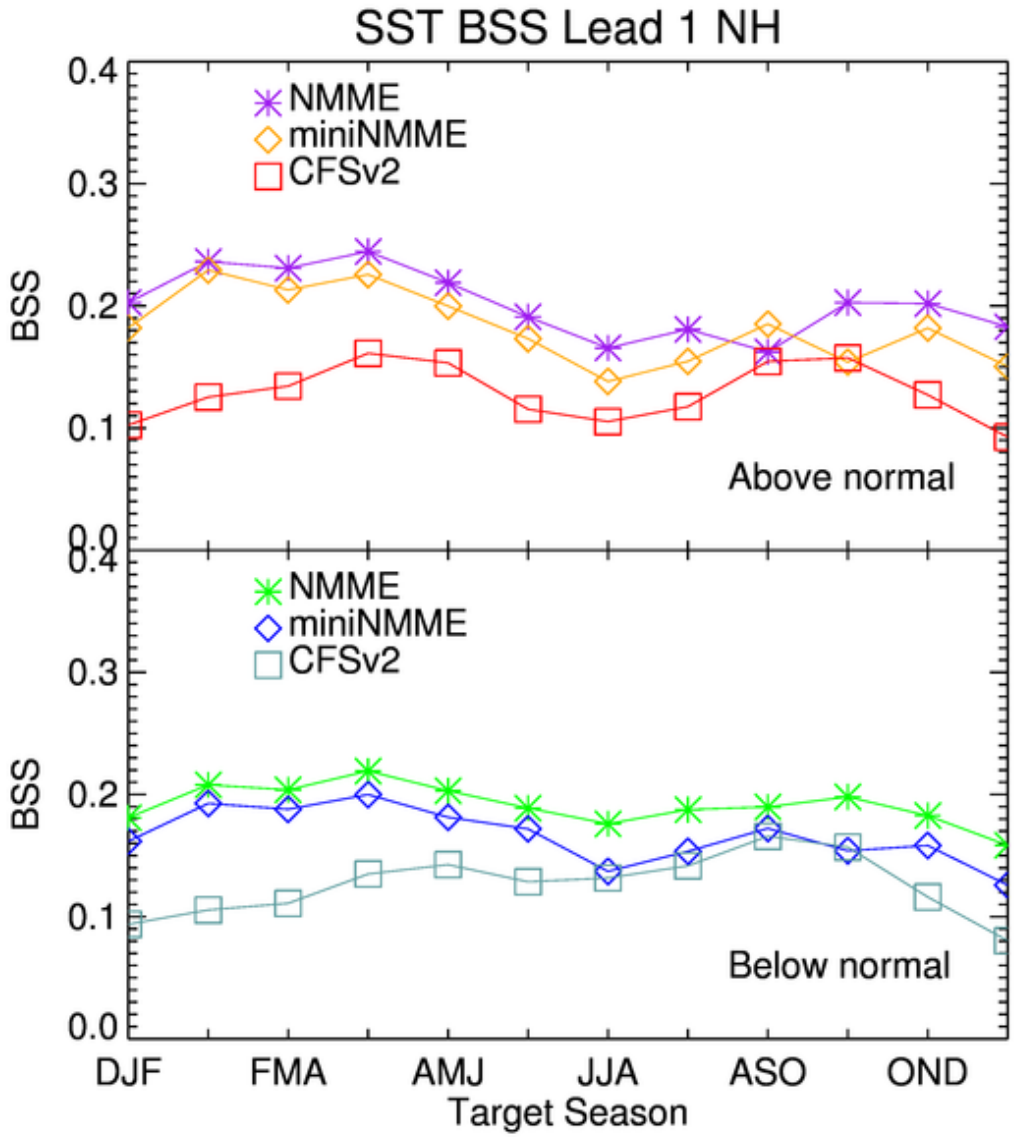
SST in the Niño3.4 region (lead-1)

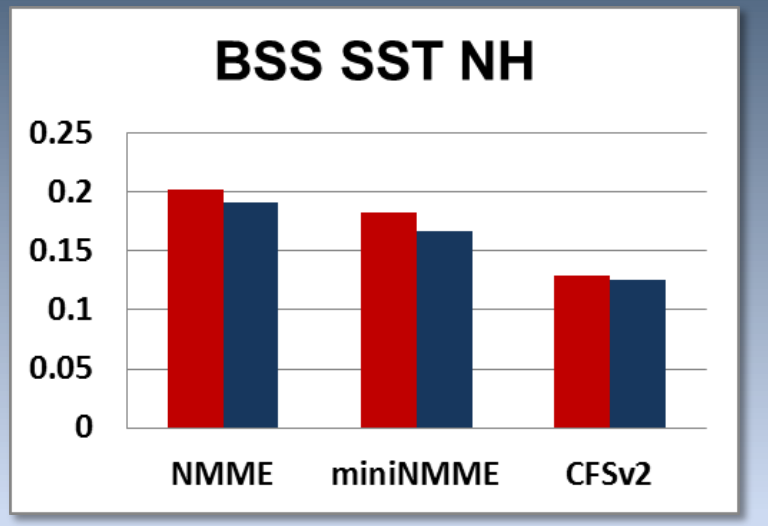




- A ~ B on average
- multi-model scores higher than CFS
- N category has some skill in MME

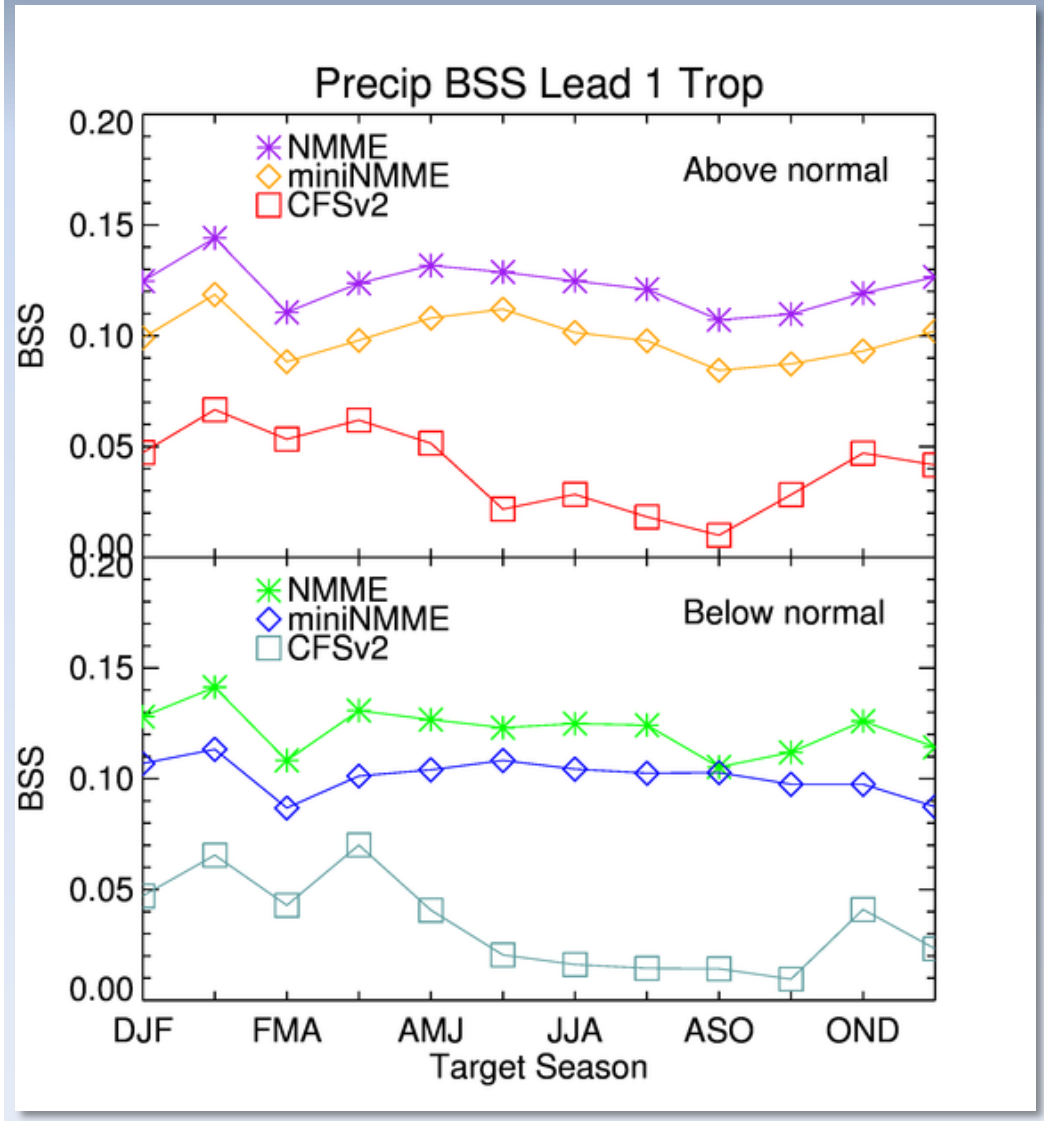
SST in Northern Hemisphere



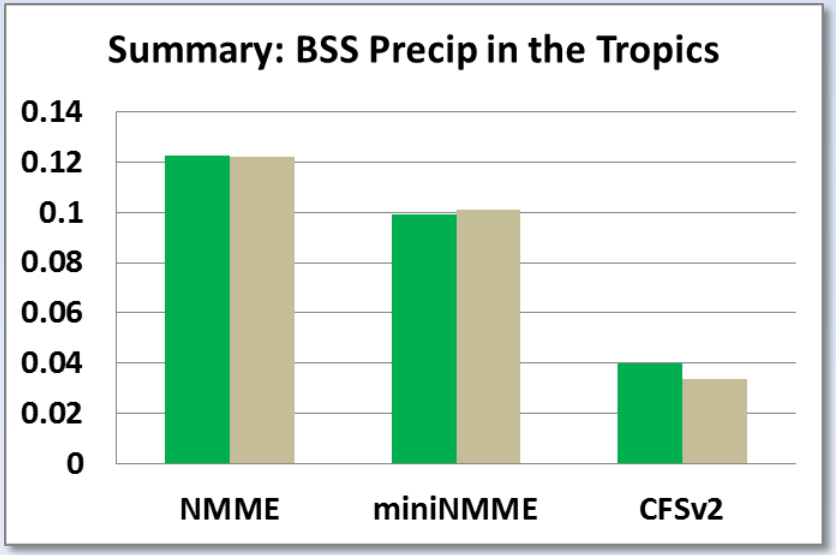


- model diversity
- this is a very large area!
- sub-basins… statistical significance of low scores

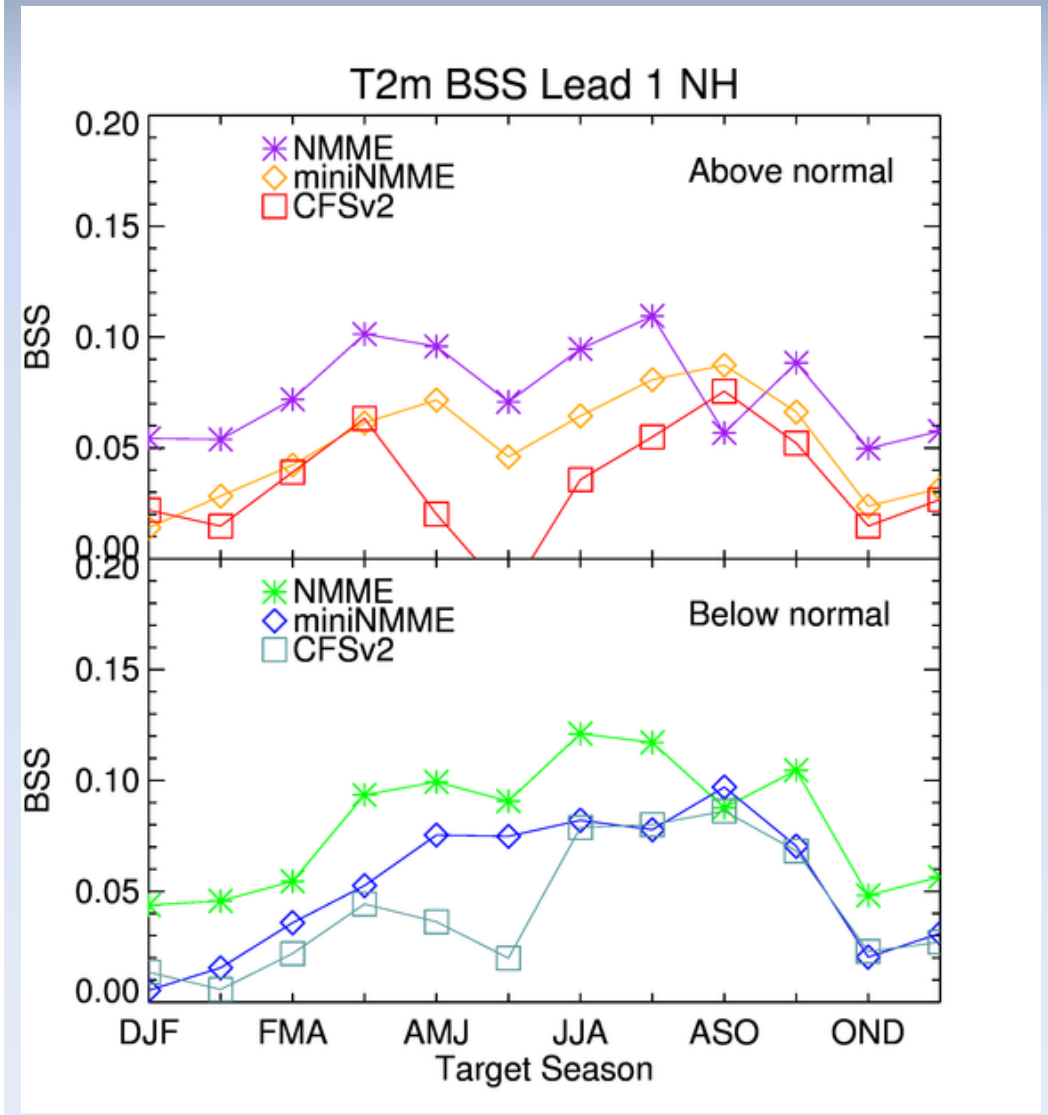
Precip rate in the tropics (land +ocean)



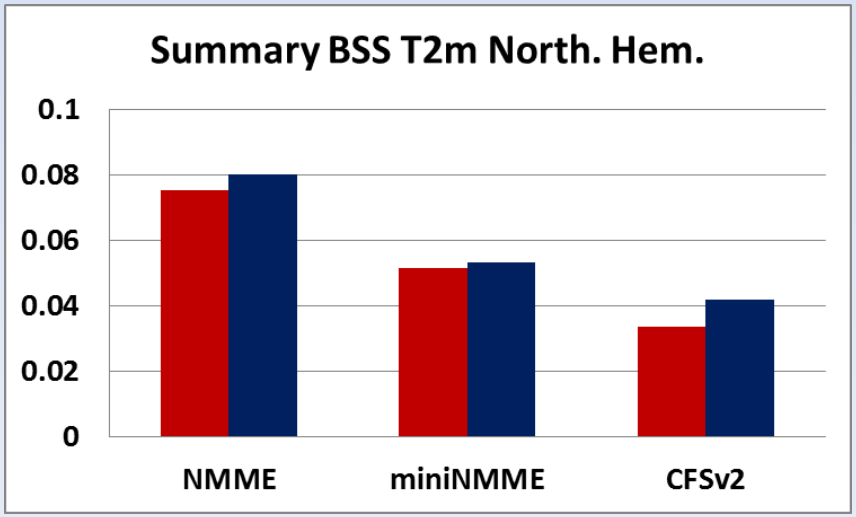
- **Larger dependence on model diversity**
- **CFSv2 skill very low during boreal summer and fall**



T2m in Northern Hemisphere



- BSS for Below-normal tercile near 0 for winter target seasons
- NMME > CFSv2 (different results from anomaly correlation)



Comments on skill of probabilistic forecasts

From baseline study…

- NMME forecasts have generally high reliability in hindcasts
- "Near normal" tercile is a very hard target to hit
- Ensemble size and model diversity have different contributions depending on field/region

More work to do…

- Experiment with parametric fit to forecast
- Probability anomaly adjustments
- More calibrations
- Size/diversity study
- Model combinations
- …

Thank you!

Information/data availability summary

- Reference article: Kirtman et al. 2014: The North American Multi-Model Ensemble (NMME): Phase-1 Seasonal to Interannual Prediction, Phase-2 Toward Developing Intra-Seasonal Prediction. http://journals.ametsoc.org/doi/abs/10.1175/BAMS-D-12-00050.1
- Currently available:
  - 1982-2010 hindcasts of monthly means, T2m, SST, prate: http://iridl.ldeo.columbia.edu/SOURCES/.Models/.NMME/
  - most forecasts, Aug 2011 – current, monthly means, bias-corrected anomalies, T2m, SST, prate: ftp://ftp.cpc.ncep.noaa.gov/NMME/realtime_anom/
- Available approximately August 2015:
  - Phase II: https://www.earthsystemgrid.org/search.html?Project=NMME
- NMME web page at CPC: http://www.cpc.ncep.noaa.gov/products/NMME/
- CPC International Desk NMME page: http://www.cpc.ncep.noaa.gov/products/international/nmme/nmme2.shtml

Verification data

- Tmp2m: GHCN+CAMS, regridded to 1° x 1° (Fan and van den Dool 2008). Land only.
- Precipitation rate (deterministic assessments): CPC global Unified Rain-Gauge Database, regridded to 1° x 1° (P. Xie et al. 2010). Land only.
- Precipitation rate (probabilistic assessments): CPC Merged Analysis of Precipitation (CMAP), (Xie and Arkin 1997). Land & ocean, regridded from 2.5°x2.5° to 1° x 1° .
- Sea-surface temperature: OI-2 (Reynolds et al. 2002), native resolution is 1° x 1°.